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Peterson, M.A.; de Gelder, B.; Rapcsak, S.Z.; Gerhardstein, P.C.; Bachoud-Levi, A.-C.

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Object memory effects on figure assignment: conscious object recognition is not necessary or sufficient

Mary A. Peterson [a,*], Beatrice de Gelder [b], Steven Z. Rapcsak [c], Peter C. Gerhardstein [a], Anne-Catherine Bachoud-Lévi [d]

[a] *Department of Psychology, University of Arizona, Tuscon, AZ 85721, USA*
[b] *Tilburg University, Tilburg, USA*
[c] *Tucson Veterans Medical Center, Tuscon, AZ 85721, USA*
[d] *Hôpital Universitaire Henri Mondor, Tuscon, AZ 85721, USA*

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Abstract

In three experiments we investigated whether conscious object recognition is necessary or sufficient for effects of object memories on figure assignment. In experiment 1, we examined a brain-damaged participant, AD, whose conscious object recognition is severely impaired. AD's responses about figure assignment do reveal effects from memories of object structure, indicating that conscious object recognition is not necessary for these effects, and identifying the figure-ground test employed here as a new implicit test of access to memories of object structure. In experiments 2 and 3, we tested a second brain-damaged participant, WG, for whom conscious object recognition was relatively spared. Nevertheless, effects from memories of object structure on figure assignment were not evident in WG's responses about figure assignment in experiment 2, indicating that conscious object recognition is not sufficient for effects of object memories on figure assignment. WG's performance sheds light on AD's performance, and has implications for the theoretical understanding of object memory effects on figure assignment.

Keywords: Object memory; Figure assignment; Object recognition

1. Introduction

For each edge, or contour, in the visual field, two regions can be defined, one lying along each side of the contour. The Gestalt psychologists showed that configural properties such as symmetry, convexity, smallness of relative area, and enclosure are among the factors that determine which one of those two regions will appear to be shaped by the contour, and which will appear to be shapeless. The shaped region is called the 'figure', and the shapeless region is often called the 'ground' because, at least for two-dimensional (2-D) displays, shapeless regions appear to continue behind shaped regions and hence, to be backgrounds to the figures. The Rubin vase/faces display shown in Fig. 1 demonstrates that conscious object recognition occurs for figures but not for grounds.

Many investigators consider the Gestalt configural cues to be low-level, or bottom-up, cues, in that they can be appraised without access to object memories. Recent research shows that some high level cues, entailing access to memories of the structure of known objects, can also affect initial figure assignment (Peterson, 1994a,b; Peterson & Gibson, 1994a,b; Peterson, Harvey & Weidenbacher, 1991; Vecera & Farah, 1997; Peterson, Gerhardstein, Mennemeier & Rapcsak, 1998). In the stimulus displays used by Peterson et al. two adjacent regions shared a contour; one region was a good depiction of a known object when it was seen as figure (called a 'high-denotative' region), whereas the other was not (called a 'low-denotative' region) (see Fig. 2). Displays were shown both upright (i.e. in the orientation in which the object in the high-denotative region was in its typical upright orientation, shown in

* Corresponding author. Tel.: +1-520-6215365; fax: +1-520-6219306.
E-mail address: mapeters@u.arizona.edu (M.A. Peterson)

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Fig. 2a–d), and inverted (i.e. misoriented from upright by a 180° rotation around the z-axis). Fig. 2e,f are inverted versions of Fig. 2c,d, respectively. Changing the orientation of these stimuli from upright to inverted does not change any of the low-level cues known to be present in the displays. Changing the orientation does change the quickness with which object recognition can be accomplished, however: access to memories of object structure is delayed for inverted objects compared to upright objects (Jolicœur, 1988; Tarr & Pinker, 1989; Ashbridge & Perrett, 1998). Therefore, orientation-dependent changes in the likelihood of seeing high-denotative regions as figures can be taken to reflect contributions to figure assignment from memories of object structure (Peterson et al., 1991; Peterson, 1994a).

Indeed, across a number of different experiments, Peterson and her colleagues found that high-denotative regions were more likely to be seen as figures when the stimuli were upright rather than inverted. Therefore, they took their findings to imply that figure assignment is affected by object memories accessed early in the course of perceptual processing. By indicating that the top/bottom spatial relationships of the parts mattered, the upright-inverted difference implied that the relevant object memories represented object structure. The orientation dependency of these effects also implied that memories of object structure must be activated quickly in order to influence figure assignment. The delay in access to memories of object structure for inverted displays seems to be sufficient to diminish or eliminate effects of object memories on figure assignment but not to eliminate conscious object recognition of inverted familiar objects once they are seen as figures (Peterson et al., 1991).

On the basis of these and other experiments Peterson et al. (1991), Peterson (1994a,b, 1999a), Peterson and Gibson (1994a,b)) proposed that, in parallel with assessments of the configural cues, memories of object

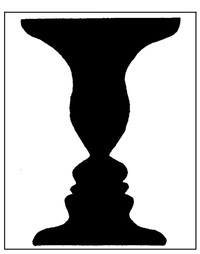

Fig. 1. The Rubin vase/faces stimulus. When the center black region is seen as the figure, it appears to have a definite shape, and the object it portrays, a vase, can be recognized; the adjacent, white region, appears locally shapeless. When the white region appears to be the figure, it appears to have a definite shape, and the objects it portrays can be recognized; the adjacent, black region appears to be shapeless. This coupling between figural status and conscious recognition led many investigators to assume that access to object memories occurred for figures only and not for grounds.

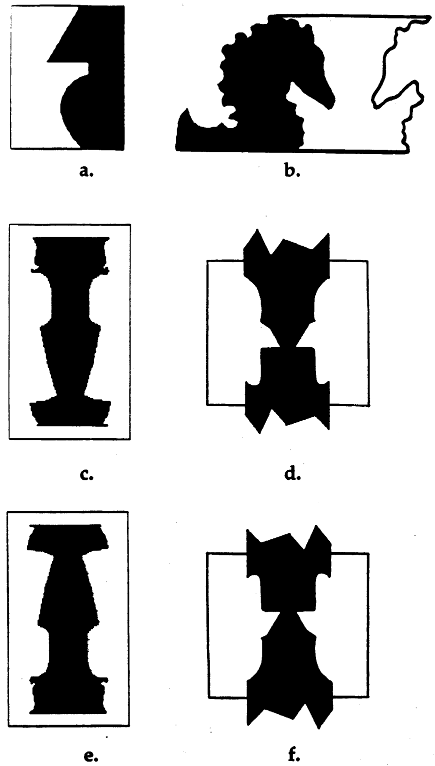

Fig. 2. Sample displays used in experiments investigating the role of object memories in figure-ground assignment. In (a), two equal-area regions share a central contour. The black region on the right is high in denotivity in that it portrays a portion of a table lamp when it is seen as figure. In (b), black and white regions equated for area and convexity share a central contour. The white region is symmetric around a vertical axis drawn through its center, but low in denotivity; whereas the black region is asymmetric and high in denotivity (it portrays a portion of a sea horse). In (c) and (d) configural cues favor the interpretation that the low-denotative black regions are the figures. They are smaller in area than the white region; in (c) the black region is symmetric and enclosed by the white region; in (d) the black region is partially symmetric and overlaps the white region (a monocular depth cue). The white regions are high in denotivity, portraying standing women in (c) and profile faces in (d). Figures (e) and (f) are inverted versions of (c) and (d). Regions that are smaller in area, enclosed, symmetric, and/or overlapping other regions when upright retain those characteristics when inverted.

structure are accessed on both sides of contours detected early in processing. On this account, object memories are accessed for regions ultimately determined to be grounds as well as for regions ultimately determined to be figures, just as the configural cues are assessed for regions on both sides of a shared contour.

The proposal that object memories are accessed sufficiently early in visual processing to affect the first figure assignment challenges a basic assumption held by many investigators of vision (e.g. Köhler, 1929; Neisser, 1967; Hochberg, 1971; Marr, 1982; Biederman, 1987; Warrington & James, 1989) who assume that object memories are accessed only by figures and not by grounds. Driver and Baylis (1995) offered an alternative account of our results that preserves the traditional assumption. They argued that observers may begin by reporting the first-perceived figure assignment as per instructions in our experiments, but their task set may change into one of looking for familiar objects after they recognize that some of the figures portray familiar objects. Once participants adopt this new strategy, they might reverse the initial figure assignment in their search for familiar objects. In that case, their reports might indicate which region portrays a familiar object rather than which region was first assigned figural status. On this alternative account, access to object memories follows figure assignment.

The ability to consciously recognize the objects portrayed by figures seems to be a necessary component of the alternative account articulated by Driver and Baylis (1995). In contrast, the ability to consciously recognize the objects portrayed by figures is not necessary to the account proposed by Peterson and her colleagues. In their view, although quick access to memories of object structure affects figure assignment, mere access to object memories in the course of perceptual organization is not sufficient for conscious object recognition; figural status is required as well (as the Rubin stimulus in Fig. 1 makes clear)[1], as is access to other types of knowledge (e.g. semantic and functional knowledge; Peterson, 1999a,b). Thus, in the view of Peterson and her colleagues, it should be possible to find object memory effects on figure assignment even when conscious object recognition is impaired.

In the two experiments reported in this paper, we investigated whether conscious object recognition is necessary or sufficient for effects of object memories on figure assignment. In experiment 1, we examined a brain-damaged participant, AD, whose conscious object recognition is severely impaired (i.e. she is a visual agnosic). We found that AD's responses about figure assignment do reveal effects from memories of object structure, indicating that conscious object recognition is not necessary for these effects. In experiments 2 and 3, we tested a second brain-damaged participant, WG, for whom conscious object recognition was relatively spared. Nevertheless, effects from memories of object structure on figure assignment were not evident in WG's responses about figure assignment in experiment 2, indicating that conscious object recognition is not sufficient for effects of object memories on figure assignment. WG's performance sheds light on AD's performance, and has implications for the theoretical understanding of object memory effects on figure assignment.

[1] Note that high-denotative regions are not necessarily seen as figures, especially when other cues compete with the effects of object memories (Peterson & Gibson, 1993, 1994a,b; Peterson, 1999a,b).

2. Experiment 1

In experiment 1, we tested the visual agnosic participant AD four times. AD was given the test of object memory effects on figure assignment (the OMEFA test) three times, twice upright (experiments 1A and 1B) and once inverted (experiment 1C). If conscious object recognition is necessary for object memory effects on figure assignment, then AD's figure reports in the OMEFA test should not reflect object memory effects, for either upright or inverted displays. If, on the other hand, conscious object recognition is not necessary for object memory effects on figure assignment, then AD's figure reports could reveal effects of object memories for upright displays (experiments 1A and 1B) but would not be expected to reveal such effects for inverted displays (experiment 1C). The OMEFA test may constitute an implicit test of access to memories of object structure in a visual agnosic participant like AD, for whom conscious object recognition is severely impaired. In experiment 1D, we evaluated AD's performance on another implicit test of access to memories of object structure — Riddoch and Humphreys (1993) real/unreal objects test — in order to investigate whether the two tests are equally sensitive indices of access to memories of object structure.

Normal (i.e. non-brain-damaged) control participants were also tested on the OMEFA test and a test of the Gestalt configural cues.

2.1. Participants

AD participated in experiments 1A–D; her case history is presented below. In addition 11 female control participants (mean age = 71.1 years, range 62–82) were given the OMEFA test and a test of Gestalt configural cue contributions to figure assignment in experiment 1A. The control participants were healthy volunteers tested at the University of Arizona after they participated in a memory study.

2.2. Case history

At the time of testing, AD was a 74 year old visual agnosic female, with bilateral temporo-occipital lesions (Fig. 3a). Her first stroke, in May 1995, resulted in damage to structures surrounding the left temporo-occipital sulcus, involving the middle occipital gyrus and inferior temporal gyrus (Brodman Areas 18, 19 and 37). In December 1995 she had a second stroke, resulting in right-hemisphere damage centered on the middle occipital gyrus, just posterior to the temporal occipital sulcus, involving area 17 and the white matter underlying area 18. For further details see Bartolomeo, Bachoud-Lévi, de Gelder, Denes, Barba, Brugieres and Degos, 1998 and de Gelder, Bachoud-Lévi and Degos (1998).

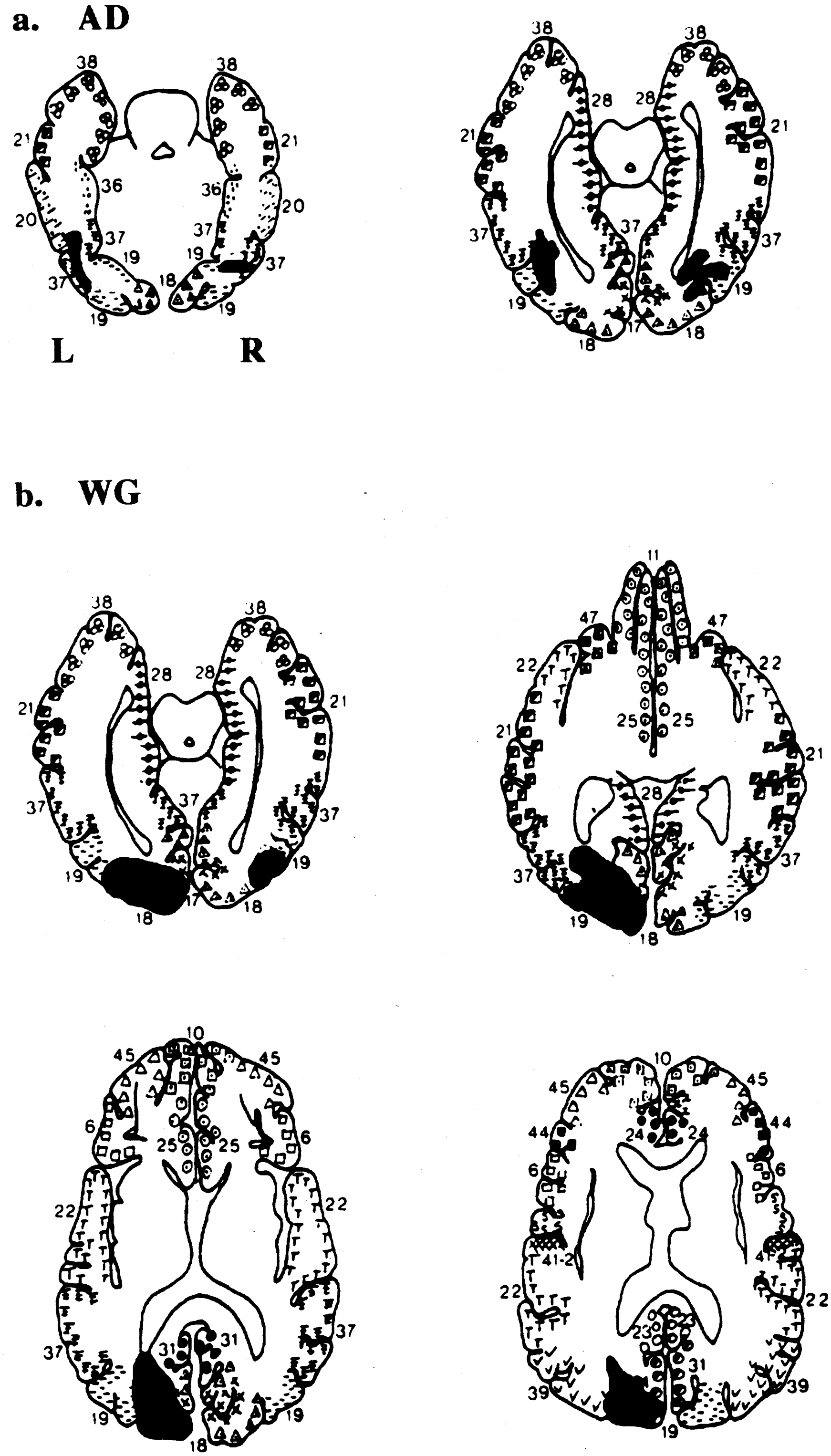

Fig. 3. (a) AD's lesion locations mapped onto Damasio and Damasio templates. (b). A map of WG's lesion locations. See text for further explication.

Our tests of AD commenced at the end of December 1996.

AD's conscious object recognition abilities were severely impaired (see Table 1 for a summary of AD's preserved and impaired capabilities. For further details, see Bartolomeo et al., 1998 and de Gelder et al., 1998). AD identified only 13/33 real objects and only 133/247 line drawings, and provided no additional information via gestures when she failed to identify an object, or did so incorrectly. Moreover, AD failed on tasks requiring her to categorize pictures based on their meaning or function (see Table 1). These behaviors indicate that AD had impaired access to semantic and functional knowledge from visual input. Even though AD was unable to reliably activate those representations necessary for conscious object recognition from visual input, she performed visual mental imagery tasks almost perfectly, and she could produce a reasonable copy of a composite drawing. These latter behaviors indicate that AD's object knowledge was preserved, even though access from visual input was severely impaired.

Table 1
AD's preserved and impaired abilities

Preserved
Position discrimination (18/20)
Dot counting (9/10)
Dot location (9/10)
Line orientation score = 25; normal
Mental imagery
Object form (24/24)
Animal size (18/19)
Drawing from name (40/40 good depictions)
Tactile naming (35/35)
Copying pictures (80/80 good copies)
Verbal IQ (WAIS − R = 109)
Impaired
Famous faces (1/40)
Farnsworth D-15 color perception (17/32)
Functional pair categorization (1/10)
Semantic pair categorization (0/10)
VOSP[a]
Silhouette naming (0/20)
Incomplete letters (14/20)
Object decision (5/20)
Object recognition
Real objects (13/33)
Line drawings (133/247)

[a] VOSP, visual object and space perception battery.

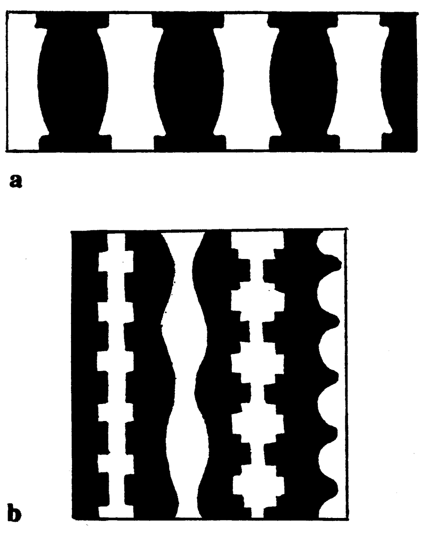

Fig. 4. Sample stimuli used in the Gestalt configural cues test. In (a) the white regions are symmetric, whereas the adjacent black regions are asymmetric. This stimulus is one of the stimuli used to test the effectiveness of symmetry as a figure cue. In (b) both black and white regions are symmetric; the black regions are also convex. This stimulus is one of the stimuli used to test the effectiveness of convexity plus as a figure cue.

2.3. Method

2.3.1. Stimuli

Three tests were used in experiment 1. One test was designed to assess the participant's use of the Gestalt configural cues to determine figure assignment. A second test was designed to assess effects of object memories on figure assignment. A third test was the real/unreal objects test from Riddoch and Humphreys (1993) Birmingham Object Recognition Battery (BORB), designed as an implicit test of access to object memories. Each of these tests is described below.

2.3.2. Gestalt configural cues test

In experiment 1A, we assessed participant's ability to use configural cues to determine figure assignment. Our test was a set of 11 stimuli depicting novel black and white (B&W) regions alternating with each other (samples are shown in Fig. 4). The number of alternating B&W regions in each stimulus ranged from 5 to 9. The alternating B&W regions were contained within a horizontally elongated rectangular frame, and were taller than they were wide; hence, they had a vertical axis of elongation. This set included stimuli testing the following configural cues and their combination: convexity* ($N = 2$), symmetry*[2] ($N = 2$), convexity* versus symmetry ($N = 4$), symmetry versus symmetry-plus-convexity* ($N = 2$), and convexity versus symmetry-plus-convexity* ($N = 1$). An asterisk marks the cue that is expected to determine figural status in each type of stimulus. Half of the regions that possessed the marked attributes were black and half were white. There were two versions of each of these stimuli; the assignment of black and white lightness to the regions in the display reversed in these two versions. Observers saw both versions of each stimulus, but they did not see the second version of any stimulus until they had seen the first version of each stimulus in the set. If responses were based on lightness alone rather than the starred configural cue, then the cued region should be reported to be figure only 50% of the time. Hence, the effectiveness of the configural cues was assessed against a baseline of 50%.

[2] The term 'symmetry' refers to whether there was reflectional symmetry around the vertical axis of the individual regions of one or the other lightness.

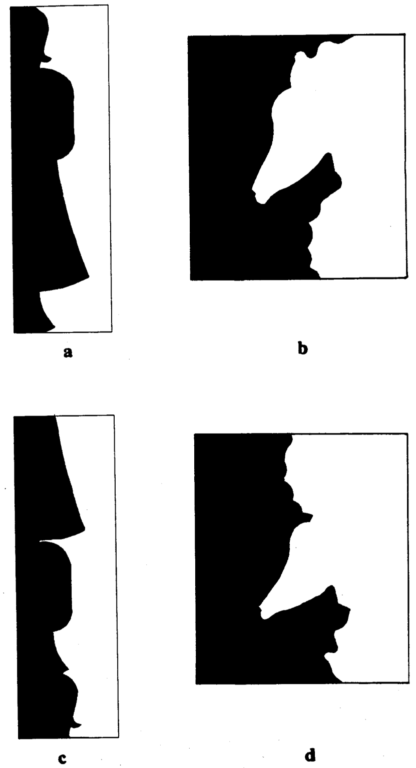

Fig. 5. The stimuli used by Peterson et al. (1998) and in the present experiments. The stimuli in the top row are experimental stimuli, in which one region is high in denotivity, whereas the adjacent region is low in denotivity. In (a), the high-denotative region portrays a standing woman in black on the left. In (b) the high-denotative region portrays a sea horse in white on the right. The stimuli in the bottom row are control stimuli in which one region is a scrambled version of a high-denotative region in an experimental stimulus. The scrambled regions in the control stimuli in the bottom row were created from the high-denotative regions of the experimental stimuli in the top row. The scrambled region created from the standing woman in (a) is black and lies on the left in the control stimulus (c) in the bottom row so that the correspondence between the high denotative region and the scrambled region can be seen clearly. The scrambled region created from the sea horse in (b) is white and lies on the right in the control stimulus (d) in the bottom row.

2.3.3. Test of object memory effects on figure assignment (OMEFA)

In experiments 1A–C, a set of 48 displays was used to assess object memory effects on figure assignment. Samples are shown in Fig. 5; these stimuli are a subset of those used by Peterson, Rapcsak and Gerhardstein (1994a,b) and Peterson et al. (1998). Each stimulus comprised two adjacent regions sharing a contour; one region was black and the other region was white. The black and white regions were approximately equal in area. Half of the stimuli ($N = 24$) were *experimental stimuli*. In the experimental stimuli, shown in the top row of Fig. 5, one region depicted a mono-oriented familiar object when it was seen as the figure/object; this object was identified correctly by at least 65% of pilot observers. Therefore, it was assumed that this 'high-denotative' region provided a good match to a representation of a known object in memory (see Appendix A for a list of the object portrayed by the high-denotative regions). High-denotative regions occurred equally often in black and in white and on the left and right sides of the shared central contour. The regions adjacent to the high-denotative regions of the experimental stimuli were 'low-denotative' in that they did not depict a known object when they were seen as figures. (Less than 22% of control observers agreed on a single interpretation for any of the low denotative regions when they were seen as figures).

The other half of the stimuli ($N = 24$) were *control stimuli*. In the control stimuli, shown in the bottom row of Fig. 5, both adjacent regions were low in denotivity. However, one region was created from a high-denotative region in the experimental set by breaking the central contour of the high-denotative regions into parts delimited by two successive concave cusps along the contour. These parts were rearranged spatially by hand (maintaining their polarity) until the resulting *scrambled* region was low in denotivity (i.e. failed to elicit greater than 22% between-observer agreement on what object it portrayed in a pilot experiment. Because of the low between-observer agreement about the object depicted by the scrambled regions and other low-denotative regions, we assumed that those regions did not provide a good match to memory representations coding the structure of the object. Like high-denotative regions, scrambled regions occurred equally often in black and in white and on the left and right sides of the shared central contour. The regions adjacent to the scrambled regions of the control stimuli were low denotative, as were the regions adjacent to the high-denotative regions of the experimental stimuli.

High-denotative regions of experimental stimuli and scrambled regions of control stimuli will be called 'critical regions'. These critical regions were equated on variables known to be relevant to figure-ground assignment (e.g. area and convexity), but differed in their goodness of fit to object representations. Thus, the stimuli in the OMEFA test were designed to assess object memory contributions to figure assignment. Specifically, object memory effects on figure assignment are implicated if observers see a larger percentage of high denotative regions of the experimental stimuli as figures than scrambled regions of the control stimuli (see Peterson, 1994a).

The stimuli ranged from 3.5 to 8.9 cm in width and from 8.0 to 13.6 cm in height. Each black and white (B&W) stimulus was drawn on a white sheet of 21.25 × 27.5 cm paper and surrounded by a frame of B&W random-dots, approximately 16 × 19.5 cm, which left a second white frame surrounding the B&W frame. Each sheet of paper was laid on top of a second sheet of 23 × 30.5 cm black paper, that provided a third, black, frame. These three frames were employed to eliminate any bias toward seeing black regions as figure that might have been present had the pictures been presented on a plain white background.

Eight additional stimuli comprised a familiarization set[3]. Six of the familiarization stimuli depicted whole known objects in either white ($N = 3$) or black ($N = 3$) silhouette on a contrasting ground surrounded by the three frames described above. The whole objects in the familiarization set were closed and smaller in area than their surrounds so that the configural cues of closure and relative area would operate to specify that they were seen as figures rather than grounds (Harrower, 1936; Rubin, 1958; Hochberg, 1971; Rubin, 1958). The objects depicted in the familiarization set were a cat, a windmill, a map of the state of Texas, a hatchet, and an airplane. Two additional familiarization stimuli, shown last, were half versions of the whole objects (the cat and the windmill) in the same style as those shown in Fig. 6a,b.

2.3.4. Real/unreal objects test

AD was also tested on sub-test 10 of the Birmingham Object Recognition Battery (BORB) (Riddoch & Humphreys, 1993). In this test, observers are asked to discriminate between real and unreal objects, where common objects and animals are rendered unreal by substituting a part of one animal or object for a similar part of another animal or object. In the easy condition, the substituted part differs substantially from the original part (e.g. a horse's head is replaced with a chicken's head. In the hard condition, the substituted part differs only slightly from the original part (e.g. the head of a snake is substituted for the head of a swan). Control observers were not tested on the BORB because Riddoch and Humphreys (1993) published norms for the test.

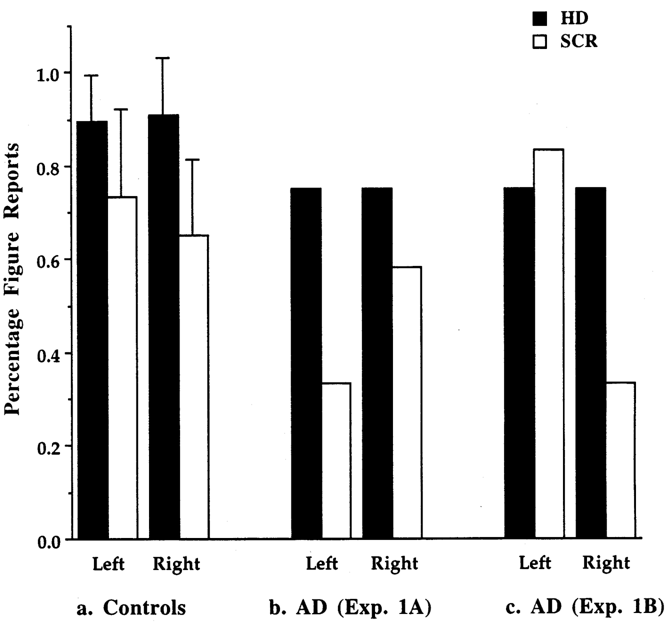

Fig. 6. The percentages of figure reports made for high-denotative regions of the experimental stimuli and scrambled regions of the control stimuli in experiment 1 by (a) eleven elderly female control participants; (b) AD, experiment 1A, upright displays; (c) AD, experiment 1B, upright displays. Percentages are shown separately for high-denotative and scrambled regions lying on the left and the right sides of the central contour.

[3] The familiarization set was not shown to AD or to the control participants tested in experiment 1. We describe the familiarization set here because it was used in experiment 2.

2.4. Procedure

AD was tested three times at Hôpital Universitaire Henri Mondor by BdG. Control participants were tested at the University of Arizona.

2.4.1. Experiment 1A

In experiment 1A, AD was first given the test of the effectiveness of Gestalt configural cues to figure assignment. She was told that, for each display, either the black or the white regions would appear to be figures in that they would appear to stand out as having a definite shape, whereas the regions of the other color would appear to form a background to the shaped figures. For each display, AD was asked to report whether the black or the white regions appeared to stand out as figures. AD had no trouble understanding these instructions, which were administered while she viewed a sample display in which the black regions were substantially smaller in area than the white regions. She responded to each of the experimental displays immediately and confidently. Stimuli remained present until response.

Immediately after the Gestalt configural cues test, AD was given the OMEFA test. AD viewed these stimuli one at a time and reported whether the black or the white region appeared to be figure, as she had done for the set of displays testing the Gestalt configural cues. She had no trouble transferring to the OMEFA test the instructions she had followed on the Gestalt configural cues test. Her 'figure' responses to each stimulus were immediate and confident, as before. After she reported which regions appeared to be figure, AD was asked to identify any familiar objects she saw. Again, these stimuli remained present until response.

Control participants were given the Gestalt configural cues test and the OMEFA test in the same order as AD.

2.4.2. Experiment 1B

In experiment 1B, conducted 3 months after experiment 1A, AD was given the OMEFA test a second time. This experiment assesses the reliability of the results of experiment 1A.

Table 2
Percentage of stimuli testing individual and combined Gestalt configural cues seen as figures by female control participants, AD, male control participants, and WG (tested on two occasions)[a]

Stimulus	Female controls		AD		Male controls		WG (1)		WG (2)	
	Mean	Cutoff	*N*	%	Mean	Cutoff	*N*	%	*N*	%
Convexity	86.4	28.5	4/4	100	87.5	62.5	3/4	75	2/4	50
Symmetry	54.5	3.1	3/4	75	81.2	29.7	4/4	100	4/4	100
S vs Cb*[b]	81.8	62.3	8/8	100	87.5	62.5	5/8	62.5	5/8	62.5
(S+C)* vs C	72.7	22.9	2/2	100	100		2/2	100	2/2	100
(S+C)* vs S	70.4	41.7	4/4	100	75	25	2/4	50	2/4	50

[a] S, symmetry; C, convexity.
[b] In cases of cue conflict, asterisks (*) indicate the cue for which choices were coded. Cut-off scores are two standard deviations below means.

2.4.3. Experiment 1C

In experiment 1C, conducted 1 week after experiment 1A, AD was given an inverted version of the OMEFA test. This experiment assessed whether AD reported seeing high-denotative regions of experimental stimuli as figures less often in inverted compared to upright displays, as normal observers do in experiments employing brief, masked exposures (e.g. Gibson & Peterson, 1994; Peterson & Gibson, 1994a).

We did not test the elderly control participants from experiment 1A in experiment 1C for the following reason. On the basis of chance alone, the high-denotative regions of inverted experimental displays should be seen as figures (objects) on approximately half the trials. Provided that object recognition processes are intact (as they are for the control participants), inverted objects can be recognized (albeit more slowly than upright objects). Therefore, we expected that control participants would recognize the objects portrayed by the inverted figures on some proportion of the trials. We were concerned that recognizing inverted objects in the displays might lead the control participants to adopt different strategies with inverted compared to upright displays.

We did not have this concern for AD because of her visual agnosia. Therefore, we chose to compare AD's performance with inverted displays to her own performance with upright displays. Peterson et al. (1991; Peterson & Gibson, 1994a,b; Gibson & Peterson, 1994) used within-subject comparisons as well.

2.4.4. Experiment 1D

Experiment 1D was conducted during the same testing session as experiment 1C. In experiment 1D, AD was given the real/unreal objects sub-test (10) of the BORB. In order to assess whether performance on this test was orientation dependent, we administered it in both upright and inverted orientations.

2.5. Results

2.5.1. Experiment 1A

2.5.1.1. Gestalt cues. Table 2 shows responses to the Gestalt configural cues test made by the control participants and AD. In all cases, AD scored above a cut-off located two standard deviations below the control mean, indicating that her use of the Gestalt configural cues for figure assignment is intact. We note that some of the control observers did not use symmetry as a cue to figure assignment, either alone or in combination with convexity. Others did not use convexity as a cue to figure assignment, either alone or in combination with symmetry. Because the number of stimuli used in this test was small, we do not dwell on these results in great detail. However, we are currently testing the use of Gestalt cues in young and elderly observers using a larger set of stimuli. The comparison of AD to the control participants suggests that AD's use of the Gestalt configural cues is not impaired.

2.5.1.2. OMEFA test. The percentages of critical regions seen as figures by both the control participants and AD are shown in Fig. 6a,b. Figure reports are shown separately for critical regions lying on the left and right sides of the central contour. As can be seen in Fig. 6a, object memory effects on figure assignment were evident in the figure reports of the control participants, who reported seeing a larger percentage of high-denotative regions of the experimental stimuli as figures (90.1%; range 79.2–100%) than scrambled regions of the control stimuli (69.2%; range 54.1–79.2%), $t(10)=7.799$, $P<0.001$. Individual difference scores (difference between the percentages of high-denotative regions of experimental stimuli and scrambled regions of the control stimuli seen as figures) ranged from 4.2[4] to 33.2%.

[4] The participant with this low difference score was biased to see left regions as figure, similar to the right-hemisphere-damaged participants tested by Peterson et al. (1998) and to college students under right visual field presentation conditions (Peterson & Gerhardstein, under review). Her difference score for right regions was large (33.3%), but was reversed for left regions (−25%).

No statistical differences were obtained between difference scores obtained for critical regions lying on the left versus the right of the central contour, $t(10) = 1.24$, n.s. We defined a bias to see critical regions lying on one side of the central contour as a tendency to see 75% or more of both types of critical regions as figures on that side (see also Peterson et al., 1998). By this measure, six control participants were biased to see left critical regions as figures and three were biased to see right critical regions as figures. These biases may reveal attentional biases mediated by the contralateral hemisphere in these observers (see Peterson et al., 1998; Peterson & Gerhardstein, under review).

Object memory effects on figure assignment were evident in AD's figure reports as well, as can be seen in Fig. 6b. AD reported seeing the high-denotative regions of the experimental stimuli as figures more often than chance (18/24 (75%), $z = 2.246$, $P = 0.\ 013$). In contrast, she did not see the scrambled regions of the control stimuli as figures more often than chance (11/24 (46%), $z = 0.24$, $P = 0.42$). The percentage of high-denotative regions AD saw as figure was approximately the same on the left and right sides of the central contour. The percentage of scrambled regions she saw as figure was larger on the right than on the left of the central contour, although this difference was not significant in a two-tailed test, $z = 1.759$, $P < 0.10$.

AD reported seeing both the high-denotative regions and the scrambled regions as figures somewhat less often than the control participants, but, in both cases, her responses fell within two standard deviations of the control mean. The percentage of the high-denotative regions of the experimental stimuli AD reported seeing as figures was larger than the percentage of scrambled regions of the control stimuli she reported seeing as figures, $z = 2.054$, $P < 0.03$. AD's difference score (29%) fell within the control participants' range (given above). AD's substantial difference score affirms that object memory effects on figure assignment are present even though her ability to identify objects consciously is severely impaired. Thus, there is no evidence that AD's performance on the OMEFA test is abnormal. It seems clear that conscious object recognition is not necessary for object memory effects on figure assignment. Next, we report identification measures obtained as part of the OMEFA test.

2.5.1.3. Identification accuracy. During the OMEFA test, participants were asked to identify the object portrayed by the figure if it was familiar. Control participants accurately identified 83.2% of the familiar objects portrayed by the high-denotative region they saw as figures (range: 68.4–95.8%). As expected on the basis of her performance on other tasks requiring object identification, AD was severely impaired at identifying the objects portrayed by the high-denotative regions she saw as figures (28%). For the remainder of the high-denotative regions, AD simply said that she saw nothing familiar.

Thus, the identification part of the OMEFA test confirms that AD's ability to consciously recognize objects is severely impaired. Because AD could identify a small percentage of the objects portrayed by the high-denotative regions she saw as figures, we recalculated the percentage of high-denotative regions she saw as figure without these stimuli (66.7%). A new difference score was also calculated for AD, using this new percentage. AD's new difference (20.9%) score remained within the normal range even when the high-denotative regions she was able to identify were removed from consideration.

The fact that AD reported a larger percentage of high-denotative regions of experimental stimuli as figures than scrambled regions of control stimuli indicates that, even though her conscious object recognition is severely impaired, access to memories of object structure from visual input occurs quickly enough to affect figure assignment. Thus, AD's performance on the test of object memories on figure assignment indicates that conscious object recognition is not necessary for object memory effects on figure assignment.

2.5.2. Experiment 1B

As can be seen in Fig. 6c, effects of object memories on figure assignment were still evident in AD's figure reports for regions lying on the right side of the central contour when she was tested 3 months later[5]. AD reported seeing high-denotative regions lying on the right side of the central contour of experimental stimuli as figure more often than expected on the basis of chance (75%; $z = 2.246$, $P < 0.013$), whereas she did not report seeing scrambled regions lying on the right side of the central contour of control stimuli as figures more often than expected on the basis of chance (33%; $z = 0.866$, $P = 0.20$). For regions lying on the right side of the central contour, AD reported seeing a larger percentage of the high-denotative regions than the scrambled regions as figures, $z = 2.919$, $P < 0.02$. These results suggest that the evidence for object memory effects on figure assignment obtained in experiment 1A was reliable.

[5] We investigated whether AD reported particular high-denotative and scrambled regions consistently as figures or grounds across experiments 1A and B. If she did it would raise a concern about the independence of the different tests. Only 25% of the scrambled regions were assigned the same figural status on these two test occasions, suggesting that for AD, memory of the figure status assigned in experiment 1A did not influence her figure reports in experiment 1B.

However, no effects of object memories on figure assignment were evident in AD's figure reports for regions lying in the left side of the central contour. Indeed, for critical regions lying on the left side of the central contour, AD reported a slightly larger percentage of scrambled regions of the control stimuli as figures than high-denotative regions of the experimental stimuli. AD's pattern of performance on the OMEFA test in experiment 1B is similar to that of college students who view brief exposures of these displays in the right visual field (RVF) (Peterson & Gerhardstein, under review) and to that of right-hemisphere (RH) damaged participants (Peterson et al., 1998). Like those two groups of participants, AD showed a bias to see left regions as figures; this bias was evident in a relatively larger percentage of figure reports for left (83.3%) versus right (33.3%) scrambled regions, $z = 3.519$, $P < 0.01$. This pattern of performance has been taken to indicate an attentional bias mediated by the left hemisphere (LH). Despite her bias to see left regions as figure, however, AD's figure reports for critical regions lying on the right side of the contour showed effects of object memories. The same is true for both RH-damaged participants and normal participants viewing briefly exposed displays in the RVF: despite their bias to see left critical regions as figures, their figure reports for critical regions lying on the right side of the contour reveal effects of object memories (Peterson & Gerhardstein, under review; Peterson et al., 1998).

AD identified only one of the objects portrayed by the high-denotative figures in this testing session; it was a figure lying on the left of the central contour. Thus, it is clear that her preference for seeing right high-denotative regions of experimental stimuli as figures over right scrambled regions of control stimuli cannot be attributed to those high-denotative regions she can identify.

Table 3
Accuracy scores for BORB sub-test ten real/unreal objects test[a]

	Easy		Hard	
	N	%	N	%
AD upright	23/32	72	19/32	59
AD inverted	15/32	47	14/32	44
Norms (upright)		95		84
Cut-off		92		80
LH-damaged (upright)		75		
Cut-off		67.5		
RH-damaged (upright)		87.5		
Cut-off		77.7		

[a] AD viewed both upright and inverted displays. Norms were gathered from participants viewing upright displays.

2.5.3. Experiment 1C

Like normal observers under brief exposure conditions, AD showed no effects of object memory on figure assignment when viewing an inverted version of the OMEFA test. Indeed, in experiment 1C, AD did not report seeing the high-denotative regions of the experimental stimuli as figure any more often than expected on the basis of chance (58.4%, $z = 0.612$, $P = 0.27$). Her figure reports for high-denotative regions of the experimental stimuli and for scrambled regions of the control stimuli (41.7%) did not differ significantly, $z = 1.158$, $P > 0.12$. Thus, for AD as for normal observers tested under laboratory conditions (e.g. Peterson et al., 1991; Gibson & Peterson, 1994; Peterson & Gibson, 1994a,b), access to memories of object structure is slowed sufficiently for inverted displays such that their influence on figure assignment is no longer evident.

Not surprisingly, AD did not identify any of the objects portrayed by high-denotative figures while viewing the inverted version of the OMEFA test.

2.5.4. Experiment 1D

AD's performance on the real/unreal objects subtest of the BORB is shown in Table 3. For both easy (72%) and hard (59%) upright stimuli, AD's accuracy scores were lower than the cut-off established by Riddoch and Humphreys (1993) on the basis of normal performance (92 and 80%, respectively). AD's scores were also below the cut-off for RH-damaged participants, although they were slightly above the cot-off for LH-damaged participants (see Table 3).

For easy BORB stimuli, AD performed better in the upright condition than in the inverted condition, $z = 2.034$, $P < 0.03$ (see Table 3). The same trend was present for hard BORB stimuli, although the difference between upright and inverted conditions was not statistically significant, $z = 1.20$, $P > 0.11$. To our knowledge, no one has shown previously that performance on the real/unreal objects test of the BORB can vary with stimulus orientation. The orientation-dependency of performance on the real/unreal objects test provides additional evidence to support the hypothesis that that memories of object structure are accessed to perform that task.

2.6. Discussion

For AD, object memory effects on figure assignment appear to be spared even though conscious object recognition is severely impaired. In experiment 1A, AD reported seeing a larger percentage of high-denotative regions of upright experimental stimuli as figures than scrambled regions of upright control. In experiment 1B, AD showed a bias to see left critical regions as figure, a pattern of behavior taken to reflect an attentional bias of the LH. Despite this attentional bias, AD's figure reports for right critical regions showed the same pattern as experiment 1A. She reported a larger percentage of high-denotative regions of the experimental stimuli as figure than scrambled regions of the control stimuli. A substantial difference between figure reports for high-denotative regions of the experimental stimuli and scrambled regions of the control stimuli is one signature of object memory effects on figure assignment.

Another signature of object memory effects on figure assignment is that they diminish or disappear when experimental stimuli are inverted (Peterson, 1994a). In experiment 1C, AD did not report seeing high-denotative regions of inverted experimental stimuli as figures more often than expected on the basis of chance.

Although AD could not identify objects consciously, it seems that her memories of object structure are accessed sufficiently quickly and sufficiently well to affect figure assignment. Thus, the OMEFA test is a new implicit test of access to memories of object structure. In experiment 1D, we measured AD's performance on another implicit test of access to memories of object structure, the real/unreal objects test. AD performed substantially below the level of control participants on the real/unreal objects test, a level of performance which has been taken to reflect impaired visual knowledge about object structure (Riddoch & Humphreys, 1993). That AD's performance was outside the normal range on the BORB real/unreal objects test, yet within normal range on the OMEFA test might indicate that the OMEFA test is a more sensitive implicit test of access to memories of object structure than the real/unreal test. In the OMEFA test, the viewer has only to report which of two adjacent regions appears to be the figure; no judgments are required about whether or not depicted objects really exist, as they are in the real/unreal objects test. For this reason, the OMEFA test may provide a measure of quick access to memories of object structure that is relatively uncontaminated by higher order processes. Alternatively, it is possible that successful performance on the real/unreal objects test of the BORB requires more detailed object processing than is needed for object memory effects on figure assignment.

One might question whether AD's reports on the OMEFA test truly reflect the first perceived figure assignment. An alternative possibility is that her figure reports for high-denotative regions of experimental stimuli might reflect a greater post-figure-assignment feeling of familiarity for those regions than for their adjacent low-denotative regions, or for either of the two regions in the control stimuli. In other words, it is possible that AD reversed the figure assignment of the displays in the OMEFA test before making her figure report. If so, then the OMEFA test may not assess the state of early access to memories of object structure. Instead, it may assess whether or not a feeling a familiarity is intact after figure assignment. Although it is not possible to be certain whether or not AD had time to reverse the figure-ground assignment and choose which of the two regions was more familiar, we do not think this alternative explanation is correct.

One reason for rejecting this alternative interpretation of AD's performance on the OMEFA test is that she performed outside the normal range on the BORB real/unreal object test but within the normal range on the OMEFA test. Hence, it seems that her figure reports in the OMEFA test are not tapping the same familiarity response tapped by the real/unreal objects test.

A second reason for rejecting the alternative interpretation is that AD performed the OMEFA test immediately after reporting figure assignment in the Gestalt configural cues test which comprised no familiar shapes. She continued to respond with the same immediacy and confidence of report on the OMEFA test as she had on the Gestalt configural cues test.

A third reason for rejecting the alternative interpretation of AD's performance is that a patient with apparently intact conscious object recognition, who was tested in experiment 2, did not show any evidence of object memory effects on figure assignment. One would expect that the strategy of reversing the initial organization and choosing the more familiar object would certainly be available to someone who can recognize objects consciously. That it apparently was not has implications for the interpretation of AD's performance, and for understanding figure assignment processes, as discussed next.

3. Experiment 2

In experiment 2, we tested a second brain-damaged individual, WG, who was able to recognize objects consciously, as assessed by standard measures. WG did not present any complaints about object recognition. He reported only that sometimes when he turned his glance to a portion of space he had looked at previously, he saw an object that had not been there before. This phenomenon could reflect mild simultanagnosia (see below).

Alternatively, this phenomenon could occur if quick access to memories of object structure were impaired in situations in which object memory effects were the only cue to figure assignment, as they are in the OMEFA test[6]. In such cases, without object memory effects on

[6] It is probably rare for only one cue to determine figure assignment in the real world, regardless of whether the cue is a configural cue or an object memory cue.

Table 4
WG's preserved and impaired abilities[a]

Preserved
Subjective contours
Line bisection
Line cancellation
Copying hierarchical stimuli
Reading
Overlapping objects with overlap lessened (97%)
Perceptual memory (Snodgrass & Corwin, 1988)
Priming for possible objects (Schacter, 1994)
Color perception
Stereo fusion
Silhouette recognition (18/18)
Hooper task (100% correct)
Boston naming task (55/60)
Identifying colored photographs of objects (12/12)
Disoriented silhouettes (Warrington & James, 1989)
Dot location
Upper left quadrant (13/14)
Lower left quadrant (9/12)
Impaired
Mooney faces (0/3)
Street figures (2/18)
Famous faces (11/26)
Matching unfamiliar faces (8/12)
S/D judgments, unfamiliar faces (13/20)
Overlapping objects task (75%)
Telegraph boy picture (simultanagnosia)
Snodgrass and Corwin picture completion
VOSP
Figure-ground (0)*
Incomplete letters (0)*
*He had an extremely conservative threshold for response, and refused to continue after completing only a few trials

[a] VOSP, visual object and space perception test (Warrington & James, 1989); S/D = same/different.

figure assignment, high-denotative regions of the visual field would be seen as figures approximately half the time, and as ground the other half the time. When seen as grounds, high-denotative regions would appear shapeless and the objects they portray would not be recognized. When seen as figures, the high-denotative regions would appear to have a definite shape, and the objects they portray would be recognized, provided that other damage did not interfere with figure recognition. If by chance alone, WG saw a high-denotative region as ground on his first glance at a region of the visual field in which object memories were the only cue to figure assignment and as figure on some subsequent glance, he might see a new object in the second glance. For this reason, we decided to administer the OMEFA test and both the Gestalt configural cue test to WG and five age-matched male control observers.

3.1. Method

3.1.1. Participants

Control participants were five normal (non-brain-damaged) elderly men from southern Arizona, who volunteered for this study (mean age = 69.4 years; range 63–75 years). Four of these men participated in the test of Gestalt configural effects on image segregation. The brain-damaged participant, WG, was tested at the Veterans Administration Medical Center in Tucson by MAP, PCG and SZR.

As part of experiment 2, AD was tested a third time with an upright version of the OMEFA test, this time with the same instructions given to WG (see Section 3.3). This test took place 11 months after experiment 1B.

3.1.2. Case history

WG was a 71-year old male, who presented with a right homonymous hemianopia that was denser in the lower quadrant. He had sustained a right-occipital stroke in 1985 and a left occipital stroke 9 weeks prior to our first testing sessions between mid-January and early February 1993. Left visual field deficits evident after the right-occipital stroke had resolved by the time of test. WG's lesions were localized in Brodman areas 18 and 19 of the RH and areas 17, 18 and 19 of the LH. A map of WG's lesion locations is shown in Fig. 3b.

As can be seen in Table 4, WG performed well within normal range on the Boston Naming Task, a standard test of conscious object recognition. In addition, WG identified all of the common objects in a set of 12 photographs developed by PCG and MAP. In these tests of conscious object recognition, there are many redundant configural cues to figure assignment; hence figure assignment does not depend upon contributions from object memories, as it does in the OMEFA test.

WG evidenced mild simultanagnosia, in that he did not perform very well on the standard overlapping objects task. However, when less extreme amounts of overlap were used, he could identify all of the objects (see Table 4). In addition, WG's identification of stimuli requiring contour completion was impaired. He performed poorly on Mooney faces, incomplete letters, both Gollin (1960) and Snodgrass and Corwin (1988) figures, and a set of fragmented objects developed by PCG and MAP in which the contour minima and maxima were recoverable despite the presence of fragmentation (see Biederman, 1987). Thus, WG clearly had some problems recognizing objects under degraded conditions.

In addition to the tests already mentioned, WG was tested with a set of 18 silhouettes of common objects, each centered on a page. He identified all of these objects correctly as well as all six of the silhouettes comprising the familiarization set for the OMEFA test.

Finally, WG made no errors in identifying a small set of partially occluded common objects ($N = 6$), five of which were silhouettes. Thus, despite some difficulties identifying degraded objects, WG's object recognition is relatively intact.

3.2. Stimuli

The set of stimuli used to test Gestalt configural cues in experiment 1 was used in experiment 2 as well. The set of stimuli used in the OMEFA test was larger than the set used in experiment 1. There were 30 experimental stimuli in the set used in this experiment (rather than 24); the number of control stimuli ($N = 24$) was the same in both sets. This set was the full set used by Peterson et al. (1994, 1998).

3.3. Procedure

All participants were given the Gestalt configural cues test and a test of silhouette recognition prior to the OMEFA test. WG was allowed to view the stimuli where he could see them best.

The instructions given to WG and the control participants for the OMEFA test were different from those given in experiment 1. Participants in experiment 2 were told that some of the displays they viewed would portray familiar objects, but that many would not; they would portray novel shapes created by the experimenters. Participants were asked to identify any known object they saw and to state whether it was black or white. They were instructed that, when they did not see a known object, they were to make an 'object decision'; that is, they were to report which region (black or white) they considered more likely to be an object.

The use of these different instructions resulted in differences in response coding. Attempts to identify the object portrayed by any region (whether correct or incorrect) were taken to indicate that region was seen a figure (because recognition is coupled to figural status). In addition, object decisions were taken to indicate that a region had a definite shape and was seen as figure. Identification responses were combined with object decisions to form an overall object decision percentage for each stimulus type. These overall object decisions are the primary data discussed below. In addition, identification accuracy was calculated for the high-denotative regions of the experimental stimuli.

3.4. Results

3.4.1. Gestalt configural cues

As can be seen in Table 2, WG's responses to Gestalt configural cues fall within the normal range, established by either the male or the female control participants. His response to convexity is weak, but some control observers had an even weaker response[7]. We note that the Gestalt test included only a small number of test trials in each condition, so the results may not be an accurate index of Gestalt configural cue contributions to figure assignment.

3.4.2. Object memory effects on figure assignment

Fig. 7 shows the results of experiment 2. The five male control participants made a larger percentage of overall object decisions for high-denotative regions of experimental stimuli than for scrambled regions of control stimuli, $t(4) = 9.699$, $P < 0.001$ (Fig. 7a). The object decisions made by one control observer for both critical region types were at ceiling for right regions (a pattern suggesting an attentional bias mediated by the RH). Nevertheless, this control participant made more overall object decisions for left high-denotative regions of the experimental stimuli (94%) than for left scrambled regions of the control stimuli (60%), $z = 2.949$, $P < 0.002$. All other control observers made more overall object decisions for high-denotative regions of the experimental stimuli than scrambled regions of the control stimuli on both the left and the right sides of the central contour. Thus effects of object memories on figure assignment were evident in all control observers.

In contrast to these five male control participants (but like four of the female control participants in

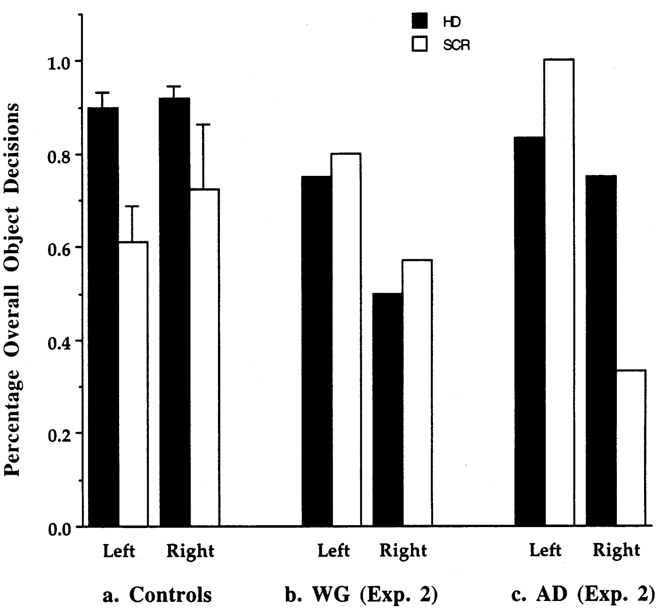

Fig. 7. The percentages of overall object decisions made for high-denotative regions of the experimental stimuli and scrambled regions of the control stimuli in experiment 2 by (a) five elderly male control participants; (b) WG; (c) AD. Object decisions for regions on the left and right sides of the central contour are shown separately.

[7] Control observers who had a weak response to convexity nevertheless showed effects of object memories on figure assignment in the OMEFA test.

experiment 1A, and like AD in experiment 1B), WG was biased to see regions lying on the left of the central contour as figure, regardless of whether they were high or low in denotivity (a pattern suggesting LH attentional bias). Furthermore, in contrast to all other participants tested, including AD, WG showed no evidence of object memory effects on figure assignment in his overall object decisions about either left or right regions. Indeed, WG made a slightly larger percentage of object decisions for scrambled regions of the control stimuli than for high-denotative regions of the experimental stimuli. This pattern of performance is highly unusual. Even when left or right biases have been reported in other non-brain damaged observers (and in many brain-damaged observers), object recognition effects on image segregation were typically evident in their responses to regions lying on the other side of the central contour (Peterson et al., 1998). However, WG failed to show influences from object memories on figure assignment for right regions as well as for left regions.

For WG, object memories do not affect figure assignment. Were object memory effects present, he should have made a larger percentage of overall object decisions for high-denotative regions of the experimental stimuli than for scrambled regions of the control stimuli, but he did not. Thus, WG's performance indicates that conscious object recognition is not sufficient for object memory effects on figure assignment.

3.4.3. Identification accuracy

Control participants identified 80% of the high-denotative regions they saw as objects. For those high-denotative regions he chose as objects, WG's identification accuracy was normal (79%)[8]. Thus, it seems that once figure assignment has occurred, WG can accurately identify familiar objects among the figures. This interpretation accords with WG's normal performance on tests of object recognition in which isolated line drawings or silhouettes were presented for identification.

WG correctly identified a larger percentage of high-denotative figures lying on the left than on the right side of the central contour (92.7 vs. 57.1%), $z = 2.01$, $P < 0.06$. Some of the control observers showed similar trends, but none showed a significant difference between right-left identification accuracy, $P\text{s} > 0.12$. Nor was a significant right-left difference found in the control means, $P > 0.20$.

3.4.4. Object decisions revisited

WG could recognize objects, and clearly could recognize the objects portrayed by the high-denotative regions he saw as figure in the OMEFA test. Therefore, it could be argued that even if object memories did not affect the initial figure assignment, WG could have reversed the figure assignment in the experimental stimuli in search of a familiar object. Such a strategy should result in more overall object decisions for high-denotative regions of experimental stimuli than for scrambled regions of control stimuli. Consequently, one might find it puzzling that WG didn't make more overall object decisions for high-denotative regions of experimental stimuli than for scrambled regions of control stimuli.

Because WG commented verbally on what he was seeing at different times during the trial, we believe that he did attempt to use such a reversal strategy, at least some of the time. However, when WG did not see a high-denotative region of an experimental stimulus as figure initially, he was unable to recognize the familiar object it portrayed when he immediately reversed the figure assignment such that the high-denotative region was the figure. This observation is important because it suggests that object memories matching regions determined to be grounds are inhibited for some time following figure assignment, as Peterson (1999b) has proposed.

3.4.5. AD's object decisions

As can be seen in Fig. 7c, despite the use of different instructions, AD's performance in experiment 2 was almost identical to her performance in experiment 1B (compare Fig. 6c and Fig. 7c)[9]. These results indicate that the differences between AD and WG cannot be attributed to the use of different instructions. Consistent with this finding, the data obtained from the control participants in experiments 1 and 2 were similar as well (compare Fig. 6a and Fig. 7a), which in itself suggests that the different instructions did not alter behavior substantially[10].

3.5. Discussion

Experiment 2 demonstrates that conscious object recognition is not sufficient for object memory effects on figure assignment. WG was able to accurately recognize the objects portrayed by high-denotative regions that he saw as figures. Nevertheless, he failed to show any influences from object memories on figure assignment.

[8] Recall, however, that WG reported a relatively small percentage of high-denotative regions as figures.

[9] AD assigned only 37.5% of the scrambled regions of the control the same status (as either figure or ground) in experiments 1B and 2.

[10] Furthermore, the performance of 12 normal female observers given the OMEFA test with the object decision instructions used in experiment 2 was compared with that of the 11 female control observers given the OMEFA test with the figure-ground instructions used in experiment 1. The means and standard deviations obtained in all conditions were approximately the same under the two different instruction conditions.

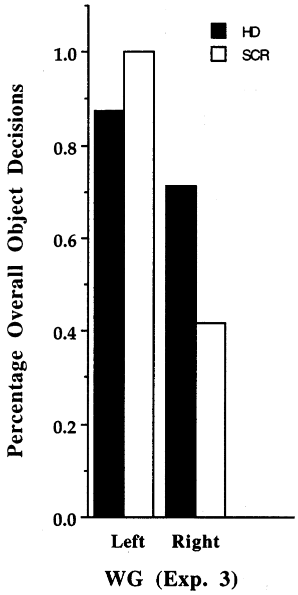

Fig. 8. Overall object decisions made by WG for high-denotative regions of the experimental stimuli and scrambled regions of the control stimuli in experiment 3, shown separately for regions lying on the left and the right sides of the central contour.

How might we then explain WG's combination of preserved conscious object recognition abilities and impaired quick access to memories of object structure? It would be reasonable to suppose that conscious object recognition requires the activation of memories of object structure as well as semantic and functional knowledge. Given that WG's conscious object recognition abilities are relatively spared, that implies that his memories of object structure must be activated eventually, even if they are not activated quickly enough to influence figure assignment. Therefore, we suppose that WG's brain damage slowed, or otherwise interfered with, initial access to memories of object structure, but did not eliminate it altogether (since his conscious object recognition was spared, at least as measured by standard tests). An analog exists in normal observers for whom inverting stimuli from their normal upright slows access to object memories sufficiently to remove object memory effects on figure assignment, but does not prevent conscious object recognition. For normal observers, conscious object recognition is slowed by stimulus inversion, but it is not eliminated. On this hypothesis, it would be reasonable to expect that WG would require more time than normal participants would to identify upright common objects. Unfortunately, we measured WG's identification accuracy, but not his identification latencies.

We return to a consideration of what WG's pattern of performance suggests regarding the question of whether or not AD's figure-ground reports were measuring object memory effects on figure assignment per se. An alternative interpretation was that AD's figure reports did not reflect initial figure assignment; and therefore, did not reflect object memory effects on figure assignment. Rather, on this alternative interpretation, her figure reports might reflect a relative familiarity judgment generated after each of the two adjacent regions in a display was seen as figure successively. However, WG's performance shows what performance on the OMEFA test would be like without object memory effects. His data are not at all similar to AD's. Instead, WG's performance suggests that shape processing is inhibited on regions determined to be grounds, which in turn suggests that a reversal strategy would be ineffective. The fact that the pattern of performance found in WG, an individual with good conscious object recognition, was different from that found in both AD and normal observers provides no support for the alternative interpretation. The interpretation we have proposed, that AD's figure reports reflect the spared operation of quick, early access to memories of object structure, remains viable.

AD's performance can be used to limit the interpretation that can be given to WG's performance, as well. Taken in isolation, the pattern of performance found in WG might be obtained if the OMEFA test were more difficult than the tests used to evaluate conscious object recognition. Evidence against a difficulty interpretation is provided by the fact that AD showed the opposite pattern of preserved and impaired abilities.

4. Experiment 3

In experiment 3, we tested WG with the OMEFA test and the Gestalt configural cues test 1.5 years after experiment 2 in order to investigate whether his brain damage interfered with initial access to object memories permanently or temporarily. During the second test administration, he was given the same instructions he had been given during the first test administration (see experiment 2). WG was also given the test assessing Gestalt configural cues again.

4.1. Results and discussion

WG's responses to the Gestalt configural cues are shown in Table 2. Once again, his responses to convexity were weak, although in all cases, his responses to Gestalt configural cues were at or above the age-matched cut-off score computed from either the male or the female control data. Thus, WG's responses to the Gestalt cue stimuli were stable across the two testing sessions.

As can be seen in Fig. 8, WG continued to show a strong preference for seeing left regions as figure in the OMEFA test. However, this time, object memory effects on figure assignment were evident for right regions. High-denotative regions of experimental stimuli (71%) were seen as figure more often than chance, $P < 0.01$, whereas scrambled regions of control stimuli were not (42%). The difference between these two percentages was large (29%), and within the range of differences shown by control observers.

WG's identification of the objects portrayed by the high-denotative regions he saw as figures was high (79%) in experiment 3, as it had been in experiment 2. Once again, he tended to identify figures lying on the left side of the central contour (86%) more accurately than those lying on the right side of the central contour (70%).

We do not take the finding that WG's results differed on first and second testing to indicate that the OMEFA test is unreliable. The test was administered to AD three times, and approximately equivalent results were obtained all three times. In addition, the test has been administered to different groups of control observers with essentially the same results. (Compare the control participants in this paper with those in the Peterson et al. (1998) paper.) Instead, we take the change in WG's performance to indicate that his brain damage did not permanently interfere with access to memories of object structure. Instead, the interference evident in experiment 2 was temporary.

The fact that the absence of object memory effects on figure assignment was temporary for WG does not diminish the importance of experiment 2. The experiments in this paper are intended as a functional description, based on neuropsychological performance, of the necessity and sufficiency of conscious object recognition for object memory effects on figure assignment. We make no claims about specific anatomical regions, given the transient nature of WG's deficit. Experiment 2 demonstrates that for upright displays, conscious object recognition is not sufficient for effects of object memories on figure assignment. It has been known for some time that conscious object recognition is not sufficient for object memory effects on figure assignment in inverted displays (e.g. Peterson et al., 1991); experiment 2 extended these results to upright displays. Moreover, the results of experiment 2 limit the interpretations that can be applied to the results of experiment 1.

5. General discussion

In experiment 1, the OMEFA test was administered to the visual agnosic patient, AD. The results showed that object memory effects on figure assignment could be observed even when conscious object recognition is severely impaired. Like normal observers, AD reported seeing a larger percentage of high-denotative regions of experimental stimuli as figures than scrambled regions of control stimuli. Thus, conscious object recognition is not necessary for object memory effects on figure assignment.

Experiment 2 showed that conscious object recognition is not sufficient for object memory effects on figure assignment. The brain-damaged participant tested in experiment 2, WG, retained his ability to recognize objects, but showed no effects of object memories on figure assignment. Unlike normal observers (and AD), WG did not report seeing a larger percentage of high-denotative regions of experimental stimuli as figures than scrambled regions of control stimuli. Because conscious object recognition presumably requires access to memories of object structure as well as access to semantic and functional knowledge, we supposed that WG's brain damage slowed, but did not eliminate, access to memories of object structure. The slowing was sufficient to remove effects of object memories on from figure assignment, but not to impair conscious object recognition. Indeed, when tested some time later in experiment 3, WG did show effects of object memories on figure assignment, suggesting that the slowing of initial access to object memories was temporary.

The demonstration that conscious object recognition is neither necessary nor sufficient for object memory effects on figure assignment rules out an argument that the relatively larger percentage of figure reports for high-denotative regions of experimental stimuli than for scrambled regions of control stimuli reflects a directed search for familiar objects. Because of her impaired conscious object recognition, AD was unable to engage in such a search. Nevertheless, she showed robust effects of object memories on figure assignment. On the other hand, WG could have engaged in such a search, given that his conscious object recognition was relatively spared (and there is some evidence that he attempted to in experiment 2). Nevertheless, WG failed to show object memory effects on figure assignment. Indeed, the results obtained in experiment 2 suggest that a strategy of searching for familiar objects would be unsuccessful, and therefore, could not account for the previous results reported by Peterson and her colleagues.

The results of experiments 1 and 2 are consistent with a model of figure assignment recently proposed by Peterson (1998, 1999) in which configural cues and object recognition cues are computed in parallel in an *interactive shape pathway* (see Fig. 9). This parallel interactive model integrates the parallel hypothesis of Peterson (1994a,b, 1998; Peterson & Gibson, 1993, 1994a,b) with some features of interactive hierarchical models of figure-ground assignment (e.g. Sejnowski & Hinton, 1987; Vecera & O'Reilly, 1998; Vecera & O'Reilly, submitted).

5.1. Parallel interactive model

In the parallel interactive model (PIM), shape processes (i.e., processes entailing configural analysis and access to memories of object structure) operate along both sides of a contour simultaneously (see also Peterson, 1994a,b, 1999a,b)[11]. Shape processes operating along the same side of a contour are interconnected via facilitatory links, and shape processes operating along opposite sides of a contour are interconnected, as an ensemble, via inhibitory links (see Fig. 9).

PIM predicts that, as the strength or number of shape cues on one side of a contour increases, inhibition sent to the shape processes operating on the other side of the contour increases as well. If the inhibition is sufficiently strong, it will not be possible to perceive shape on the inhibited side of the contour. According to PIM, the perception of shape attributes such as symmetry versus asymmetry, convexity vs. concavity, closure, area, familiarity versus novelty is necessary for the perception of shape. If the processes assessing these attributes are inhibited, shape cannot be seen. Similarly, if these processes are inhibited, robust access to higher-level structures necessary for conscious object recognition (i.e. include semantic and functional knowledge) does not occur; consequently, conscious object recognition cannot occur. Therefore, the inhibited side of the contour will be seen as a shapeless ground.

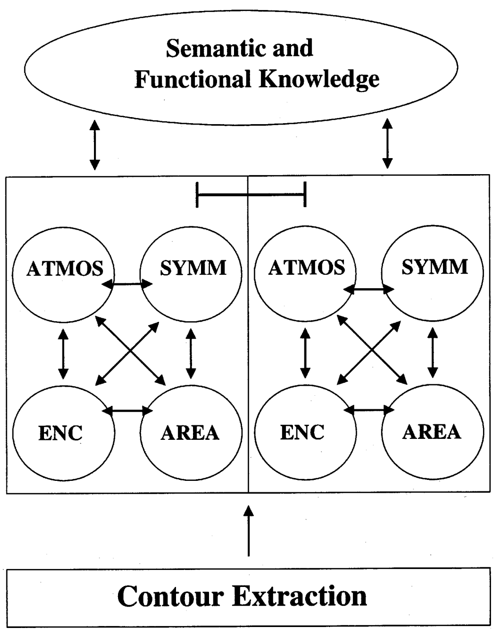

Fig. 9. The parallel interactive model (PIM). A selection of shape processes are shown operating on both sides of a contour extracted early in processing, including ATMOS (access to memories of object structure); SYMM (symmetry), ENC (enclosure); and AREA. Facilitatory connections exits between shape processes operating on the same side of a contour (indicated by double-headed arrows); inhibitory connections exits between shape processes operating on opposite sides of a contour (indicated by T-endings). Feed forward and feedback connections between levels are also indicated by double headed arrows.

[11] PIM includes shape processes only; it is assumed that depth cues are processed in a different pathway.

On the other hand, the shape processes operating on the side of the contour ultimately seen as the shaped figure are not inhibited. The facilitatory connections between shape processes operating on the same side of the contour can boost the activation of initially weak shape processes. Robust access to the higher-level structures required for conscious recognition can be made by these shape processes, and provided that brain damage does not interfere with access to (or feedback from) those higher-level structures, the object portrayed on the shaped side of the contour should be recognized consciously. Thus, without positing a separate figure-ground stage of processing, as other models have done (Vecera & O'Reilly, 1998; Peterson, 1999a), PIM can account for the fact that figures appear to have a definite shape whereas grounds appear to be shapeless.

According to PIM, it should be possible to sustain brain damage like AD's that interferes with conscious recognition of objects but spares quick, early access to memories of object structure; it is the latter process that affects figure assignment. Such damage would most likely affect access from shape processes to functional and semantic knowledge (and/or feedback from this knowledge to shape processes). It should also be possible to sustain brain damage like WG's that interferes with quick early access to memories of object structure but leaves conscious object recognition relatively intact. This is because, on the PIM model, initial deficiencies in access to object memories may be overcome by either feed-back from semantic and functional knowledge (if those connections are intact) or by facilitatory connections from other shape processes operating on the same side of the contour.

The present set of experiments also produced results consistent with the PIM proposal that shape processing is inhibited on regions determined to be grounds in the course of image segregation. WG was unable to recognize objects portrayed by high-denotative regions that were not initially determined to be figures (i.e. were not initially determined to be shaped), even when he intentionally reversed the figure-ground assignment in an attempt to find familiar objects. This finding suggests that shape processing (including access to object memories) was inhibited on high-denotative regions that were not initially seen as figures.

Further research is needed to assess the adequacy of PIM as a model of figure assignment. The proposal that access to object memories is inhibited for ground regions arises uniquely from the PIM proposal that object memories are accessed along both sides of a shared contour in parallel with the assessment of configural cues. We are particularly intrigued by the evidence for inhibition obtained in the present paper. Peterson (1999b) is currently investigating whether or not inhibition of shape processes operating on ground regions can be observed in normal observers.

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Appendix A. Object portrayed by the high-denotative regions of the experimental stimuli

Apple	Pear
Bell	Pine tree
Bulb	Pineapple
Coffee pot	Sea horse
Cow	Snow man
Deciduous tree	Stop sign
Face profile	The letter F
Guitar	Toilet
Hand	Umbrella
House	Wine glass
Lamp	Woman
Milk can	Wrench

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